

# Reviews, Tables, and Plots



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PDG

LBNL

Advisory Committee Meeting  
24 September 2006

## First, my fascinating biennial overview of changes in REVIEWS, TABLES, AND PLOTS!

### Constants, Units, Atomic and Nuclear Properties

1. Physical constants (revised)
2. Astrophysical constants (revised—WMAP3)
3. International System of Units (SI)
4. Periodic table of the elements (revised)
5. Electronic structure of the elements (revised!)
6. Atomic and nuclear properties of materials (NEW AtomicNuclearProperties)
7. Electromagnetic relations (transmission lines revised)
8. Naming scheme for hadrons

### Standard Model and Related Topics

Private version to be  
nationalized shortly

9. Quantum chromodynamics (revised)
10. Electroweak model and constraints on new physics (revised)
11. The Cabibbo-Kobayashi-Maskawa quark-mixing matrix (NEW)
12.  $CP$  violation (revised)
13. Neutrino mass, mixing, & flavor change (revised)
14. Quark model (revised)
15. Grand Unified Theories (revised)
16. Structure functions (revised)
17. Fragmentation functions in  $e^+e^-$  annihilation (revised)

## Astrophysics and cosmology

18. Experimental tests of gravitational theory (revised)
19. Big-Bang cosmology (revised—WMAP3)
20. Big-Bang nucleosynthesis (revised)
21. The cosmological parameters (revised—WMAP3)
22. Dark matter (revised)
23. Cosmic microwave background (revised—WMAP3)
24. Cosmic rays (revised) (Needs rewritten, but there are chronic problems)

## Experimental Methods and Colliders

25. Accelerator physics of colliders (revised; 2008 rewrite promised)
26. High-energy collider parameters (revised)
27. Passage of particles through matter (revised—3 new sections)
28. Particle detectors (revised)
29. Radioactivity and radiation protection (revised; 2008 rewrite promised)
30. Commonly used radioactive sources

## Mathematical Tools or Statistics, Monte Carlo, Group Theory

31. Probability
32. Statistics (revised)
33. Monte Carlo techniques (revised)
34. Monte Carlo particle numbering scheme (revised)
35. Clebsch-Gordan coefficients, spherical harmonics, and  $d$  functions
36.  $SU(3)$  isoscalar factors and representation matrices
37.  $SU(n)$  multiplets and Young diagrams

## Kinematics, Cross-Section Formulae, and Plots

38. Kinematics
39. Cross-section formulae for specific proc. (revised)
40. Plots of cross sections and related quantities (revised)

### In summary:

- 83% of the 40 REVIEWS, TABLES, AND PLOTS are new or revised for 2006
- If the 60 minireviews (of various majorness) are included, 70% of the 100 items are new or revised for this edition



# A big upgrade of AtomicNuclearProperties--- (close to being the official version)

Atomic and Nuclear Properties of Materials  
for 292 substances

This AtomicNuclearProperties page is under intermittent development. Suggestions and comments are welcome.

**CHEMICAL ELEMENTS:** For entries in **red**, a pull-down menu permits selection of physical state. Cryogenic liquid densities are at the boiling point at 1 atm. **Black** symbols are not linked. **PLEASE REPORT ERRORS.**

Click on periodic table for elements

Pull down menus for about 200 mixtures and compounds

Simple compounds (Acetone—Ethane)

Simple compounds (Ethanol—Methane)

Simple compounds (Methanol—Xylene)

Polymers

Mixtures

Biological materials

The  $dE/dx$  and range algorithms are described in D.E. Groom, N.V. Mokhov, and S.I. Striganov, "Muon stopping-power and range tables, 10 MeV--100 TeV," Atomic Data and Nuclear Data Tables 78, 183-336 (2001). Nearly-identical tables for many of the materials are given.

(Can be found at </home/sierra/~deg/AtomicNuclearProperties>)

Gases and a few others (in red) have properties for different physical states

**Atomic and Nuclear Properties of Materials  
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0 <sup>0</sup> H																	2 <sup>2</sup> He					
1 <sup>1</sup> Ps																						
1 <sup>1</sup> H																						
3 <sup>3</sup> Li																	5 <sup>5</sup> B	6 <sup>6</sup> C	7 <sup>7</sup> N	8 <sup>8</sup> O	9 <sup>9</sup> F	10 <sup>10</sup> Ne
11 <sup>11</sup> Na																	13 <sup>13</sup> Al	14 <sup>14</sup> Si	15 <sup>15</sup> P	16 <sup>16</sup> S	17 <sup>17</sup> Cl	18 <sup>18</sup> Ar
19 <sup>19</sup> K	20 <sup>20</sup> Ca	21 <sup>21</sup> Sc	22 <sup>22</sup> Ti	23 <sup>23</sup> V	24 <sup>24</sup> Cr	25 <sup>25</sup> Mn	26 <sup>26</sup> Fe	27 <sup>27</sup> Co	28 <sup>28</sup> Ni	29 <sup>29</sup> Cu	30 <sup>30</sup> Zn	31 <sup>31</sup> Ga	32 <sup>32</sup> Ge	33 <sup>33</sup> As	34 <sup>34</sup> Se	35 <sup>35</sup> Br	36 <sup>36</sup> Kr					
37 <sup>37</sup> Rb	38 <sup>38</sup> Sr	39 <sup>39</sup> Y	40 <sup>40</sup> Zr	41 <sup>41</sup> Nb	42 <sup>42</sup> Mo	43 <sup>43</sup> Tc	44 <sup>44</sup> Ru	45 <sup>45</sup> Rh	46 <sup>46</sup> Pd	47 <sup>47</sup> Ag	48 <sup>48</sup> Cd	49 <sup>49</sup> In	50 <sup>50</sup> Sn	51 <sup>51</sup> Sb	52 <sup>52</sup> Te	53 <sup>53</sup> I	54 <sup>54</sup> Xe					
55 <sup>55</sup> Cs	56 <sup>56</sup> Ba	57 <sup>57</sup> La	72 <sup>72</sup> Hf	73 <sup>73</sup> Ta	74 <sup>74</sup> W	75 <sup>75</sup> Re	76 <sup>76</sup> Os	77 <sup>77</sup> Ir	78 <sup>78</sup> Pt	79 <sup>79</sup> Au	80 <sup>80</sup> Hg	81 <sup>81</sup> Tl	82 <sup>82</sup> Pb	83 <sup>83</sup> Bi	84 <sup>84</sup> Po	85 <sup>85</sup> At	86 <sup>86</sup> Rn					
87 <sup>87</sup> Fr	88 <sup>88</sup> Ra	89 <sup>89</sup> Ac	104 <sup>104</sup> Rf	105 <sup>105</sup> Db	106 <sup>106</sup> Sg	107 <sup>107</sup> Bh	108 <sup>108</sup> Hs	109 <sup>109</sup> Mt	110 <sup>110</sup> Ds	111 <sup>111</sup> Rg	112	114										
			58 <sup>58</sup> Ce	59 <sup>59</sup> Pr	60 <sup>60</sup> Nd	61 <sup>61</sup> Pm	62 <sup>62</sup> Sm	63 <sup>63</sup> Eu	64 <sup>64</sup> Gd	65 <sup>65</sup> Tb	66 <sup>66</sup> Dy	67 <sup>67</sup> Ho	68 <sup>68</sup> Er	69 <sup>69</sup> Tm	70 <sup>70</sup> Yb	71 <sup>71</sup> Lu						
			90 <sup>90</sup> Th	91 <sup>91</sup> Pa	92 <sup>92</sup> U	93 <sup>93</sup> Np	94 <sup>94</sup> Pu	95 <sup>95</sup> Am	96 <sup>96</sup> Cm	97 <sup>97</sup> Bk	98 <sup>98</sup> Cf	99 <sup>99</sup> Es	100 <sup>100</sup> Fm	101 <sup>101</sup> Md	102 <sup>102</sup> No	103 <sup>103</sup> Lr						

Physical states:  
☐ 1 H Hydrogen gas  
☐ 1 H Hydrogen liquid  
☐ 1 D Deuterium gas  
☐ 1 D Deuterium liquid

Simple compounds (Acetone—Ethane)

Simple compounds (Ethanol—Methane)

Simple compounds (Methanol—Xylene)

Polymers

Mixtures

Biological materials

The  $dE/dx$  and range algorithms are described in D.E. Groom, N.V. Mokhov, and S.I. Striganov, "Muon stopping-power and range tables, 10 MeV--100 TeV," Atomic Data and Nuclear Data Tables 78, 183-356 (2001). Nearly-identical tables for many of the materials are given.

(Can be found at </home/sierra/~deg/AtomicNuclearProperties>)

## Now table format and with several new features---

### Atomic and nuclear properties of materials:

#### Iron (Fe)

Quantity	Value	Units	Value	Units
Atomic number	26			
Atomic mass	55.845	g mole <sup>-1</sup>		
Density	7.87	g cm <sup>-3</sup>		
Minimum ionization	1.451	MeV g <sup>-1</sup> cm <sup>2</sup>	11.43	MeV cm <sup>-1</sup>
Radiation length	13.84	g cm <sup>-2</sup>	1.757	cm
Nuclear collision length	81.7	g cm <sup>-2</sup>	10.37	cm
Nuclear interaction length	132.1	g cm <sup>-2</sup>	16.77	cm
Critical energy (e <sup>-</sup> )	21.81	MeV		
Molière radius	13.45	cm	1.709	cm
Muon critical energy	347	GeV		
Melting point	1811.	K	1538.	C
Boiling point @ 1 atm	3134.	K	2861.	C

For some things

[Explanation of some entries](#)

Table of muon  $dE/dx$  and Range: [PS](#) [PDF](#) [TEXT](#)

[Table of isotopes](#)

[x ray mass attenuation coefficients](#)

As before

### Atomic and nuclear properties of materials:

#### Acetone (CH<sub>3</sub>CHCH<sub>3</sub>)

Quantity	Value	Units	Value	Units
<Z/A>	0.55097			
Density	0.790	g cm <sup>-3</sup>		
Minimum ionization	2.003	MeV g <sup>-1</sup> cm <sup>2</sup>	1.582	MeV cm <sup>-1</sup>
Radiation length	41.27	g cm <sup>-2</sup>	52.25	cm
Nuclear collision length	57.5	g cm <sup>-2</sup>	72.75	cm
Nuclear interaction length	81.4	g cm <sup>-2</sup>	103.0	cm
Critical energy (e <sup>-</sup> )	(Pending)	MeV		
Molière radius	(Pending)	g cm <sup>-2</sup>	(Pending)	cm
Muon critical energy	1160.	GeV		

### Composition:

Elem	Z	Atomic frac*	Mass frac
H	1	6.00	0.104122
C	6	3.00	0.620405
O	8	1.00	0.275473
* calculated from mass fraction data.			

[Explanation of some entries](#)

Table of muon  $dE/dx$  and Range: [PS](#) [PDF](#) [TEXT](#)

## Astrophysics and cosmology:

After nontrivial revision, there was an 11th hour emergency update to include the newly published WMAP3 results.

⇒ The new results are more definitive, with improved errors, but not different.

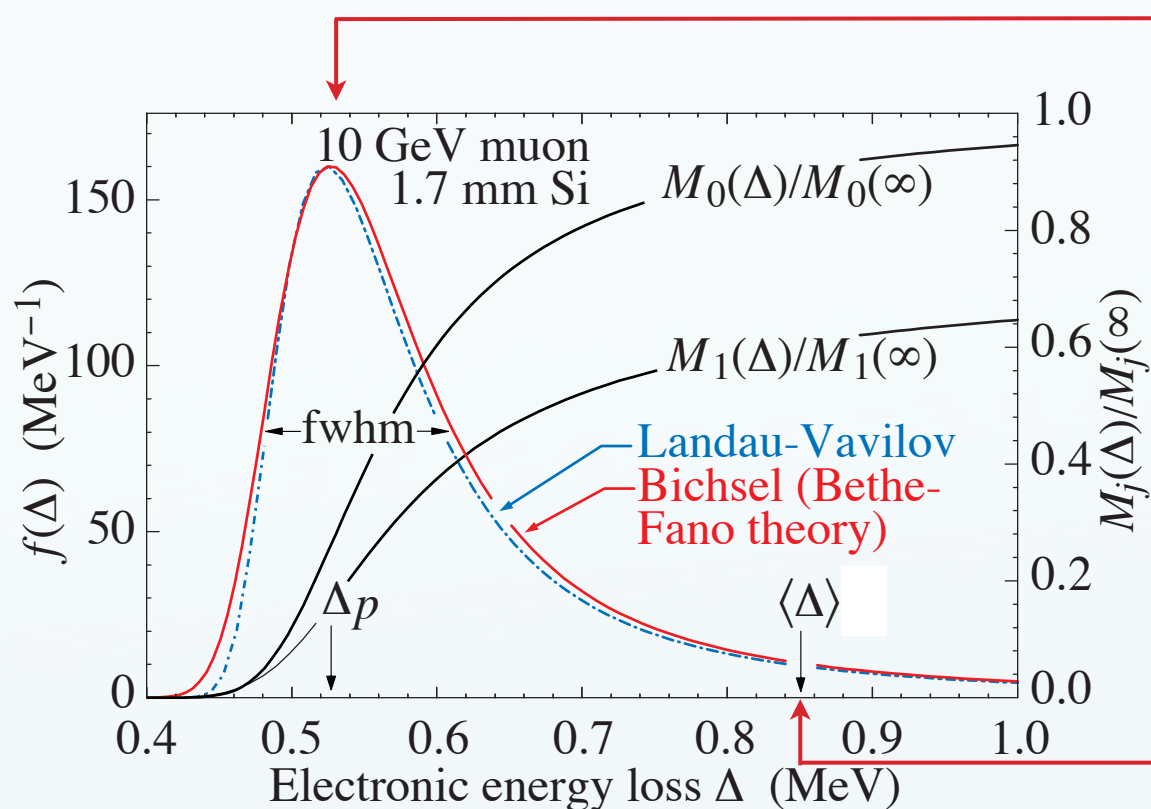
Keith Olive not only co-authors “Big-Bang Cosmology,” but coordinates and oversees all the others.\* I’m just a spectator.

\* Except for Thibault Damour’s “Experimental tests of relativity”, which is self-propelled, and “Cosmic rays,” which is a major problem



## Passage of particles through matter:

A minor-looking change which we will be further improved in 2008



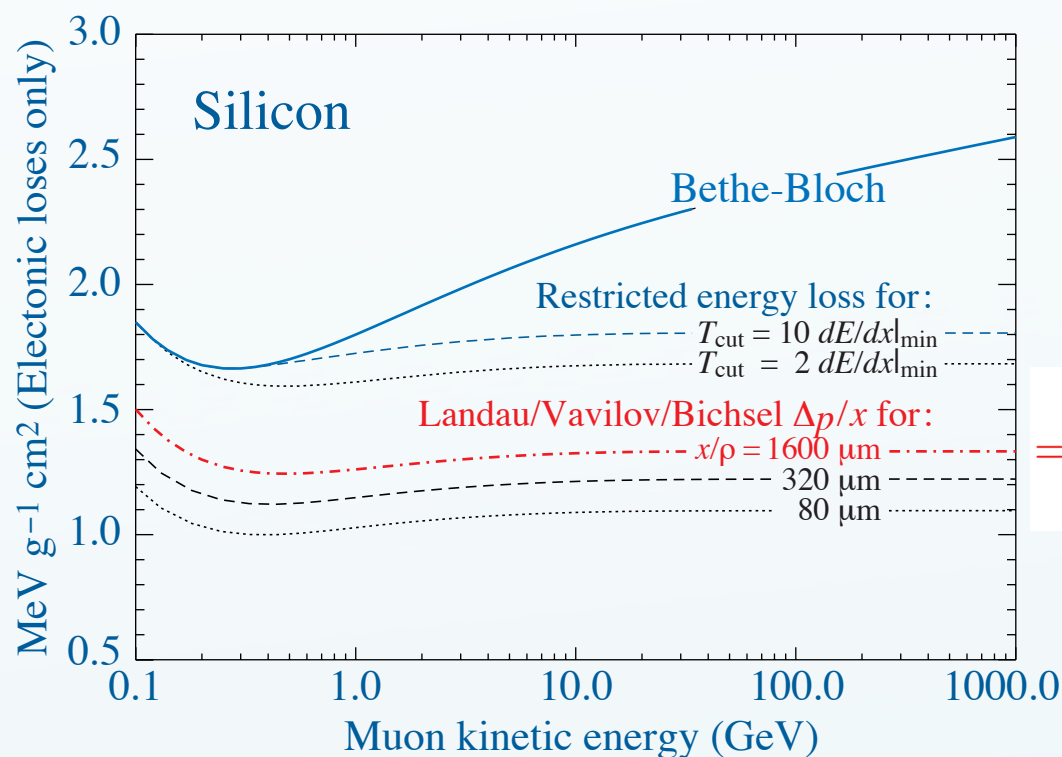
Most probable energy loss is  $\approx$  independent of  $\gamma$  at “normal” test-beam energies

(Figure is for RPP08)

Bethe-Bloch  $IdE/dx$  increases with  $\ln \gamma$  because of more  $\delta$ -rays “way out in the tail”

“The expression  $dE/dx$  should be abandoned; it is **never** relevant to the signals in a particle-by-particle analysis”

-- Hans Bichsel [NIM A 562 (2006) 154-197]



$$\Rightarrow C \frac{1}{\beta^2} \left[ \ln \frac{2m_e c^2 C x}{(\hbar \omega_p)^2} + 0.200 \right]$$

Particle detectors: Changes long on the to-do list have been made!

The most substantial addition is “Photon Detection”

Authors: Dhiman Chakraborty (Northern Illinois U; FNAL), and  
Takayuki Sumiyoshi (Tokyo Metropolitan U).

Almost-author referees: John Elias, Peter Denes

Sample of the new section’s scope:

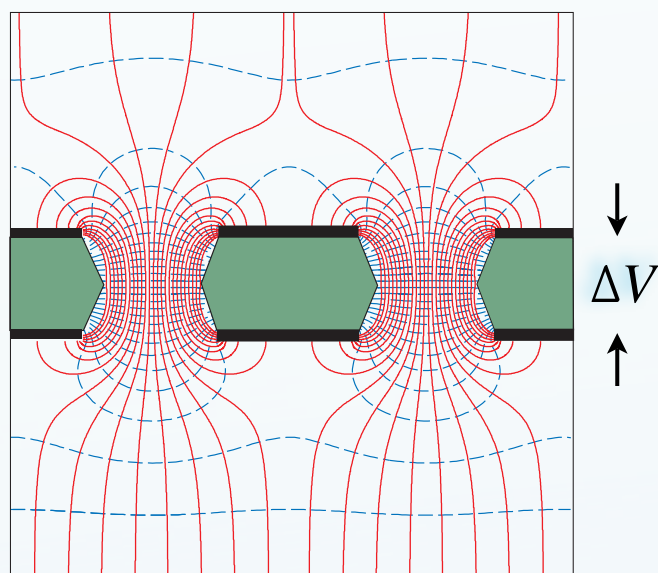
**Table 28.2:** Representative characteristics of some photodetectors commonly used in particle physics. The time resolution of the devices listed here vary in the 10–2000 ps range.

Type	$\lambda$ (nm)	$\epsilon_Q \epsilon_C$	Gain	Risetime (ns)	Area (mm <sup>2</sup> )	1-p.e noise (Hz)	HV (V)	Price (USD)
PMT*	115–1100	0.15–0.25	$10^3$ – $10^7$	0.7–10	$10^2$ – $10^5$	$10$ – $10^4$	500–3000	100–5000
MCP*	100–650	0.01–0.10	$10^3$ – $10^7$	0.15–0.3	$10^2$ – $10^4$	0.1–200	500–3500	10–6000
HPD*	115–850	0.1–0.3	$10^3$ – $10^4$	7	$10^2$ – $10^5$	$10$ – $10^3$	$\sim 2 \times 10^4$	$\sim 600$
GPM*	115–500	0.15–0.3	$10^3$ – $10^6$	$O(0.1)$	$O(10)$	$10$ – $10^3$	300–2000	$O(10)$
APD	300–1700	$\sim 0.7$	$10$ – $10^8$	$O(1)$	$10$ – $10^3$	$1$ – $10^3$	400–1400	$O(100)$
SiPM	400–550	0.15–0.3	$10^5$ – $10^6$	$\sim 1$	1–10	$O(10^6)$	30–60	$O(10)$
VLPC	500–600	$\sim 0.9$	$\sim 5 \times 10^4$	$\sim 10$	1	$O(10^4)$	$\sim 7$	$\sim 1$

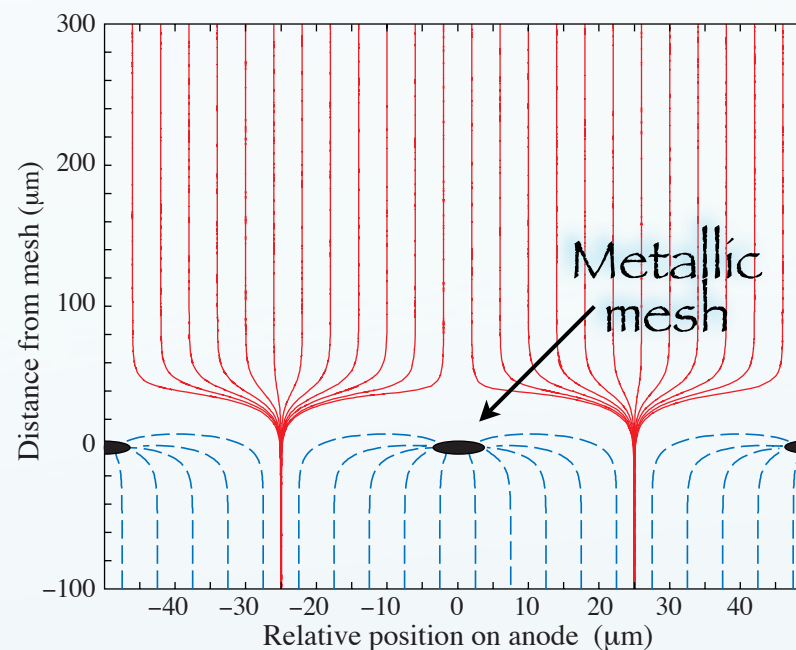
\*These devices often come in multi-anode configurations. In such cases, area, noise, and price are to be considered on a “per readout-channel” basis.

Two new micro-pattern gas detectors (MPGD's) (Mike Ronan):

Gas-electron multiplier  
(GEM)



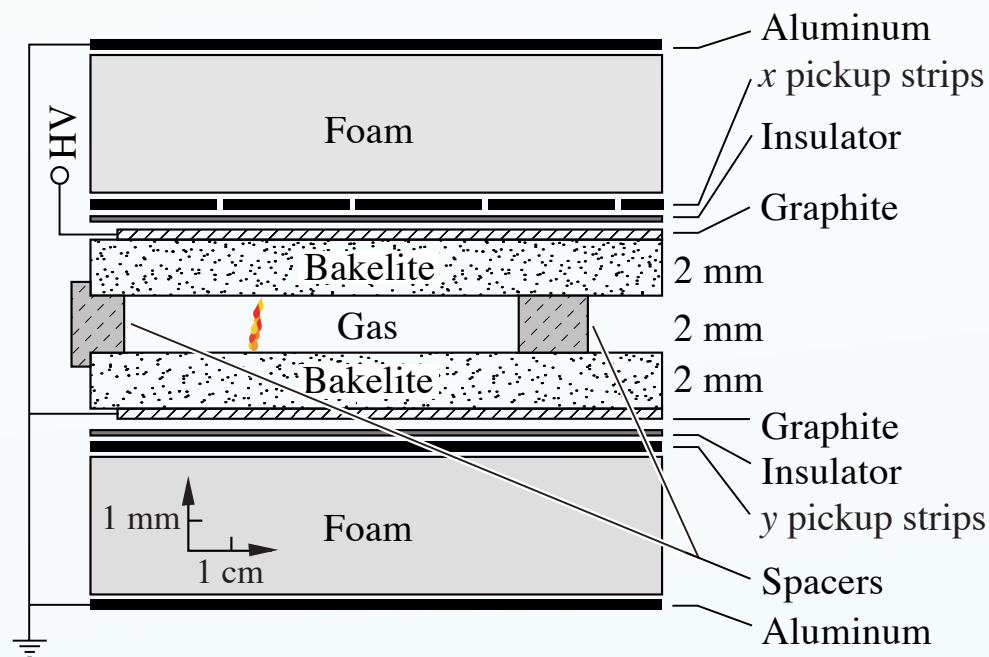
Micromegas



Supply substantial amplification, direct electron signals, and suppression of positive-ion feedback; useful in TPC's and other gas detectors



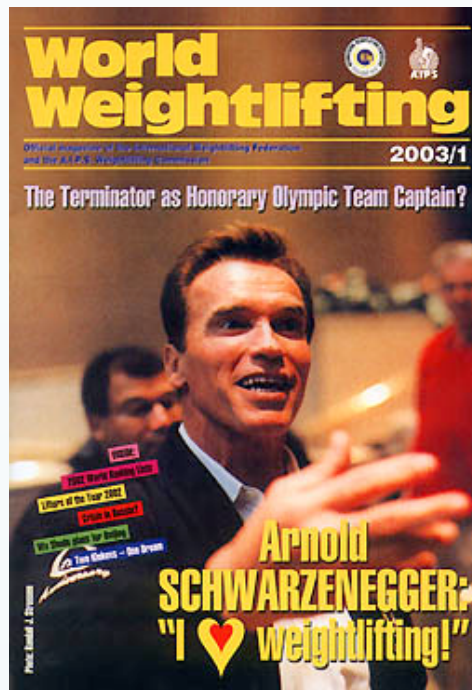
And the resistive plate chamber  
 (RPC) the Advisory Committee  
 has been beating me up about  
 for so long!  
 (Henry Band, J. Zhang)



Finally, progress but  
 No Cigar Yet on the  
 modernization of  
 hadron calorimetry



After all these years, Groom's paper is  
 in process with NIM A. Richard Wigmans  
 has agreed to collaborate with him on  
 the new section for RPP08



26 (!) pages for the axion minireview?



Thank you!